

and use good engineering judgment to repeat the calibration. We recommend that you use a calibration subsonic venturi or ultrasonic flow meter and simulate exhaust temperatures by incorporating a heat exchanger between the calibration meter and the exhaust-flow meter. If you can demonstrate that the flow meter to be calibrated is insensitive to exhaust temperatures, you may use other reference meters such as laminar flow elements, which are not commonly designed to withstand typical raw exhaust temperatures. We recommend using calibration reference quantities that are NIST-traceable within 0.5% uncertainty.

(b) You may remove system components for off-site calibration. When installing a flow meter with an off-site calibration, we recommend that you consider the effects of the tubing configuration upstream and downstream of the flow meter. We recommend specifying calibration reference quantities that are NIST-traceable within 0.5% uncertainty.

(c) If you use a subsonic venturi or ultrasonic flow meter for raw exhaust flow measurement, we recommend that you calibrate it as described in § 1065.340.

**§ 1065.340 Diluted exhaust flow (CVS) calibration.**

(a) *Overview.* This section describes how to calibrate flow meters for diluted exhaust constant-volume sampling (CVS) systems.

(b) *Scope and frequency.* Perform this calibration while the flow meter is installed in its permanent position. Perform this calibration after you change any part of the flow configuration upstream or downstream of the flow meter that may affect the flow-meter calibration. Perform this calibration upon initial CVS installation and whenever corrective action does not resolve a failure to meet the diluted exhaust flow verification (i.e., propane check) in § 1065.341.

(c) *Reference flow meter.* Calibrate a CVS flow meter using a reference flow meter such as a subsonic venturi flow meter, a long-radius ASME/NIST flow nozzle, a smooth approach orifice, a laminar flow element, a set of critical flow venturis, or an ultrasonic flow

meter. Use a reference flow meter that reports quantities that are NIST-traceable within  $\pm 1\%$  uncertainty. Use this reference flow meter's response to flow as the reference value for CVS flow-meter calibration.

(d) *Configuration.* Do not use an upstream screen or other restriction that could affect the flow ahead of the reference flow meter, unless the flow meter has been calibrated with such a restriction.

(e) *PDP calibration.* Calibrate a positive-displacement pump (PDP) to determine a flow-versus-PDP speed equation that accounts for flow leakage across sealing surfaces in the PDP as a function of PDP inlet pressure. Determine unique equation coefficients for each speed at which you operate the PDP. Calibrate a PDP flow meter as follows:

(1) Connect the system as shown in Figure 1 of this section.

(2) Leaks between the calibration flow meter and the PDP must be less than 0.3% of the total flow at the lowest calibrated flow point; for example, at the highest restriction and lowest PDP-speed point.

(3) While the PDP operates, maintain a constant temperature at the PDP inlet within  $\pm 2\%$  of the mean absolute inlet temperature,  $\bar{T}_{in}$ .

(4) Set the PDP speed to the first speed point at which you intend to calibrate.

(5) Set the variable restrictor to its wide-open position.

(6) Operate the PDP for at least 3 min to stabilize the system. Continue operating the PDP and record the mean values of at least 30 seconds of sampled data of each of the following quantities:

(i) The mean flow rate of the reference flow meter,  $\bar{n}_{ref}$ . This may include several measurements of different quantities, such as reference meter pressures and temperatures, for calculating  $\bar{n}_{ref}$ .

(ii) The mean temperature at the PDP inlet,  $\bar{T}_{in}$ .

(iii) The mean static absolute pressure at the PDP inlet,  $\bar{p}_{in}$ .

(iv) The mean static absolute pressure at the PDP outlet,  $\bar{p}_{out}$ .

(v) The mean PDP speed,  $\bar{f}_{nPDP}$ .

(7) Incrementally close the restrictor valve to decrease the absolute pressure at the inlet to the PDP,  $\bar{p}_{in}$ .

(8) Repeat the steps in paragraphs (e)(6) and (7) of this section to record data at a minimum of six restrictor positions reflecting the full range of possible in-use pressures at the PDP inlet.

(9) Calibrate the PDP by using the collected data and the equations in § 1065.640.

(10) Repeat the steps in paragraphs (e)(6) through (9) of this section for each speed at which you operate the PDP.

(11) Use the equations in § 1065.642 to determine the PDP flow equation for emission testing.

(12) Verify the calibration by performing a CVS verification (i.e., propane check) as described in § 1065.341.

(13) Do not use the PDP below the lowest inlet pressure tested during calibration.

(f) *CFV calibration.* Calibrate a critical-flow venturi (CFV) to verify its discharge coefficient,  $C_d$ , at the lowest expected static differential pressure between the CFV inlet and outlet. Calibrate a CFV flow meter as follows:

(1) Connect the system as shown in Figure 1 of this section.

(2) Start the blower downstream of the CFV.

(3) While the CFV operates, maintain a constant temperature at the CFV inlet within  $\pm 2\%$  of the mean absolute inlet temperature,  $\bar{T}_{in}$ .

(4) Leaks between the calibration flow meter and the CFV must be less than 0.3 % of the total flow at the highest restriction.

(5) Set the variable restrictor to its wide-open position.

(6) Operate the CFV for at least 3 min to stabilize the system. Continue operating the CFV and record the mean values of at least 30 seconds of sampled data of each of the following quantities:

(i) The mean flow rate of the reference flow meter,  $\bar{n}_{ref}$ . This may include several measurements of different quantities, such as reference meter pressures and temperatures, for calculating  $\bar{n}_{ref}$ .

(ii) Optionally, the mean dewpoint of the calibration air,  $\bar{T}_{dew}$ . See § 1065.640 for permissible assumptions.

(iii) The mean temperature at the venturi inlet,  $\bar{T}_{in}$ .

(iv) The mean static absolute pressure at the venturi inlet,  $\bar{p}_{in}$ .

(v) The mean static differential pressure between the CFV inlet and the CFV outlet,  $\Delta\bar{p}_{CFV}$ .

(7) Incrementally close the restrictor valve to decrease the absolute pressure at the inlet to the CFV,  $p_{in}$ .

(8) Repeat the steps in paragraphs (f)(6) and (7) of this section to record mean data at a minimum of ten restrictor positions, such that you test the fullest practical range of  $\Delta\bar{p}_{CFV}$  expected during testing. We do not require that you remove calibration components or CVS components to calibrate at the lowest possible restrictions.

(9) Determine  $C_d$  and the lowest allowable  $\Delta\bar{p}_{CFV}$  as described in § 1065.640.

(10) Use  $C_d$  to determine CFV flow during an emission test. Do not use the CFV below the lowest allowed  $\Delta\bar{p}_{CFV}$ , as determined in § 1065.640.

(11) Verify the calibration by performing a CVS verification (i.e., propane check) as described in § 1065.341.

(12) If your CVS is configured to operate more than one CFV at a time in parallel, calibrate your CVS by one of the following:

(i) Calibrate every combination of CFVs according to this section and § 1065.640. Refer to § 1065.642 for instructions on calculating flow rates for this option.

(ii) Calibrate each CFV according to this section and § 1065.640. Refer to § 1065.642 for instructions on calculating flow rates for this option.

(g) *SSV calibration.* Calibrate a subsonic venturi (SSV) to determine its calibration coefficient,  $C_d$ , for the expected range of inlet pressures. Calibrate an SSV flow meter as follows:

(1) Connect the system as shown in Figure 1 of this section.

(2) Start the blower downstream of the SSV.

(3) Leaks between the calibration flow meter and the SSV must be less than 0.3 % of the total flow at the highest restriction.

(4) While the SSV operates, maintain a constant temperature at the SSV inlet within  $\pm 2\%$  of the mean absolute inlet temperature,  $\bar{T}_{in}$ .

(5) Set the variable restrictor or variable-speed blower to a flow rate greater than the greatest flow rate expected during testing. You may not extrapolate flow rates beyond calibrated values, so we recommend that you make sure the Reynolds number,  $Re^\#$ , at the SSV throat at the greatest calibrated flow rate is greater than the maximum  $Re^\#$  expected during testing.

(6) Operate the SSV for at least 3 min to stabilize the system. Continue operating the SSV and record the mean of at least 30 seconds of sampled data of each of the following quantities:

(i) The mean flow rate of the reference flow meter,  $\bar{n}_{ref}$ . This may include several measurements of different quantities, such as reference meter pressures and temperatures, for calculating  $\bar{n}_{ref}$ .

(ii) Optionally, the mean dewpoint of the calibration air,  $\bar{T}_{dew}$ . See §1065.640 for permissible assumptions.

(iii) The mean temperature at the venturi inlet,  $\bar{T}_m$ .

(iv) The mean static absolute pressure at the venturi inlet,  $\bar{p}_m$ .

(v) Static differential pressure between the static pressure at the venturi inlet and the static pressure at the venturi throat,  $\Delta\bar{p}_{SSV}$ .

(7) Incrementally close the restrictor valve or decrease the blower speed to decrease the flow rate.

(8) Repeat the steps in paragraphs (g)(6) and (7) of this section to record data at a minimum of ten flow rates.

(9) Determine a functional form of  $C_d$  versus  $Re^\#$  by using the collected data and the equations in §1065.640.

(10) Verify the calibration by performing a CVS verification (i.e., propane check) as described in §1065.341 using the new  $C_d$  versus  $Re^\#$  equation.

(11) Use the SSV only between the minimum and maximum calibrated flow rates.

(12) Use the equations in §1065.642 to determine SSV flow during a test.

(h) *Ultrasonic flow meter calibration.*  
[Reserved]

Figure 1 of §1065.340—Schematic diagrams for diluted exhaust flow (CVS) calibration.

